Physiological work areas in professional beach volleyball: A case study
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Abstract: In this paper, physiological areas of professional beach volleyball players are identified by combining notational analysis tools together with in-sync heart rate capture for specific time periods in competition games. The aim is to identify workload areas depending on the player’s position as well as the changes these areas undergo during real competitions. To this end, a case study is quantitatively analyzed and based on the Spanish National Team during the First International Training Tournament «Sixto Jimenez» played in Tenerife (Spain). Workload ranges differ between blocker player (from 77.71% to 89.13%) and defensive player (from 66.16% to 77.77%), both values are related to their individual HRmax. Furthermore, median HRmax values indicate that blocker player must support an increased workload of 84.78% compared to 71.71% of the defending player. Therefore, the specific position of the defenders established significant differences in their physiological responses.

Keywords: Beach volleyball, performance analysis, Sportcode, heart rate, Polar Team.

Introduction

The study of physiological areas has been an important part of knowledge that helps to learn about the special characteristics of a wide variety of sports. In this way, it is necessary to distinguish the real physiological work areas to be able to develop correct and specific sport training. For this reason, not only in beach volleyball, but also in other sports, like boxing (Alvarez Berta, Cascón Zagalaz, Ibrahim, & Mateos Padorno, 2014) badminton (Alvarez, Campos, Portes, Roy, & Martin, 2016) triathlon (Zapico, Benito, Diaz, Ruiz, & Calderón, 2014), and football (soccer) (Casamichana, San Román-Quintana, Castellano, & Calleja-González, 2012; Nikolaidis, Ziv, Amron, & Lidor, 2015; Pasqual Verdú, Orbea Palacios, Carbonell, Alejandro, & Tossi, 2015), there are studies that establish work areas.

On the one hand, there is evidence that internal load patterns in different sports are related to the quantity of volumes and intensities found during training or actual game situations and that they improve the performance of players (González Fimbres, Griego Amaya, Cuevas Castro, & Hernández Cruz, 2016).

On the other hand, there are a few studies related to the physiological response in beach volleyball players. Due to the interest of researchers working in these areas different studies have been conducted to establish physiological responses (Davies, 2000; Lorenz, Roll, Wiebke, & Jeschke, 2002). A study on the impact analysis and neuromuscular real beach volleyball games in the recovery of players has also been published (Magalhães, Inacio, Oliveira, Ribeiro, & Ascensao, 2011).

These physiological responses have a direct relationship with different factors such as the rules of the game (Giatisis, 2003), the field, the number of players and the environmental conditions (Palao, Valadés, Manzanares, & Ortega, 2014). Of all these conditions mentioned so far, the most studied one has been the playing surface. The sand hinders the movement of players (Smith, 2006), but thanks to this fact, players have developed specific patterns of movement for beach volleyball (Cortell-Tormo, Perez-Turpin, Chinchilla-Mira, Cejuela, & Suarez, 2011; Perez-Turpin, Cortell-Tormo, Suarez-Llorca, Chinchilla-Mira, & Cejuela-Anta, 2009). The playing field forces players to perform more complex movements (Koch & Tilp, 2009a, 2009b) along different tactical areas which sometimes they must play (Bahr & Reeser, 2012) affect and modify the heart rate of players (Coyle, 2004).

However, there is little knowledge about the physiological response of professional beach volleyball players in real games. In this study, a detailed analysis of heart rate values during a real game on a professional beach volleyball team is conducted as a case study. The main goal is to get insight into the actual physical demands on these players to provide information about the requirements of performance and subject physiological response.

Methodology

Materials and Methods

The case study focuses on a two-man Spanish beach volleyball team (Table 1), playing the most important beach volleyball competition, the FIVB World Tour.

Data collection was performed after players were informed about the aims and objectives of the study, giving their consent according to the guidelines of the Ethics Committee of the University of Alicante.

<table>
<thead>
<tr>
<th>Age</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>194.6</td>
<td>82.00</td>
</tr>
</tbody>
</table>

Note: Both players are universal players, non-specific role.

Two games of the First International Training Tournament «Sixto Jimenez» were analyzed, carried out in the high performance center T3

Table 1: Player’s data

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Tenerife in the Canary Islands on the 1st, 2nd and 3rd of April, 2011. The games discussed correspond with quarters and semifinals played in the afternoon. This tournament brought some of the best European teams.

Videotape was made with a semi-professional mini-DV video camera, which was located in the frontal plane to capture the full field at a distance of 5.5 m from the end line on a step. In order to obtain a valid picture for further analysis, the camera is stabilized on a tripod with a lens at 3.5 m off the ground. This position of the camera allows the user to see clearly all the actions carried out during the recording of the game in both sides of the field (Callejon, 2006).

On the one hand, the heart rate values from both players were registered in real time using the monitoring system Polar Team II. On the other hand, video analysis was performed using the software SportCode Pro v. 8.5.2.

Procedure design

Visualization and analysis of video recordings were carried out by two experienced observers (Koch & Tilp, 2009b). To ensure reliability of observation during the study, two intra-operator views were performed. For each of the videos and variables analyzed, error rate was computed based on the following mathematical expression (Hughes, 2004): Error (%) = (Σ(mod(V1-V2))/Vmean) * 100 where V1 and V2 are the frequencies of the first and second operator observation, respectively, Vmean is the mean value of the two registered observation frequencies and mod is the modulus. The intra-observer analysis reliability gave a margin of error of less than 5% (James, Taylor, & Stanley, 2007) which falls within acceptable margins of error in the visualization and analysis.

Players were monitored with Polar Team Pro II. Each player used this device while playing, and at the same time, the games were recorded to analyze the active time (AT) in relation to heart rate values. Heart rate values were analyzed in real game by synchronizing the game video with the heart rate video. This allows researchers to obtain real values of heart rate in each moment at a pace of one HR reading per second and player. Active time (AT) and rest time per player in passive time (PT) were also registered in real time (Table 2).

<table>
<thead>
<tr>
<th>AT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT</td>
<td>Time since the first contact in serve since the ball touch the sand.</td>
</tr>
<tr>
<td>PT</td>
<td>Time since ball touched the sand at the previous point since the player that are doing the service touch the ball at the first push.</td>
</tr>
</tbody>
</table>

Each period was registered with heart rate values displayed on the screen of polar team application. Therefore, the different heart rate values that depended on the duration of the game were considered (Figure 1). All heart rate frequencies were codified using the software SportCode Pro v 8.5.2.

In order to classify heart rate values in time spans of interest, the following four periods were defined:
- Set 1: Actions during the first set
- Set 2: Actions during the second set

Also, all techniques for each of the players’ actions were counted within these periods. The following techniques were recorded (Koch & Tilp, 2009b):
- Block.
- Reception.
- Defense.
- Setting.
- Attack.
- Serve.

Therefore, the analysis procedure is summarized as follows:
- Recording and digitization of images.
- Synchronization of video recordings to be merged into one video.
- Definition of code arrays containing the proper elements to be analyzed.
- Coding of images with each of the defined codes.

Data were analyzed using SPSS v.22 to perform descriptive statistics. After Kolmogorov-Smirnov normal test, the statistical test applied was a non-parametric test U Mann-Whitney to compare both means between players and between different and established time periods.

Results

The values obtained as a result of the implementation of the methodology and research design are presented. First, a stress test of each of the players was carried out to obtain the maximum heart rate value and to, then, calculate the working areas during the real game (Table 3).

<table>
<thead>
<tr>
<th>Set 1</th>
<th>Time</th>
<th>Final BP (mmHg)</th>
<th>HRmax (bpm)</th>
<th>Resp. rate (l/min)</th>
<th>VO2max (ml/kg/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Player 1</td>
<td>8.08</td>
<td>172/99</td>
<td>164</td>
<td>39</td>
<td>4.140</td>
</tr>
<tr>
<td>Player 2</td>
<td>11</td>
<td>160/100</td>
<td>184</td>
<td>53</td>
<td>5.196</td>
</tr>
</tbody>
</table>

Note: Final BP = Final blood pressure; HRmax = Maximum heart rate; Resp. rate = Respiratory rate VO2 = Oxygen consumption; VO2max = Maximal oxygen uptake

The analysis of the active time in which heart rate values were recorded establishes working ranges for each player. For Player 1 (blocker), a minimum of 90 bpm and a maximum of 180 bpm were recorded, with a working range between 143 bpm and 164 bpm. These

![Figure 1](image-url)
values reveal a workload between 77.71% and 89.13% of his maximum heart rate (HRmax), while the median of the pulse rate is at 156 ± 21 bpm, which is 84.78% of his HRmax. Similarly, Player 2 (defender) showed a minimum heart rate of 108 bpm and a maximum of 188 bpm, with a working range between 131 bpm and 154 bpm. In this case, workload remains between 66.10% and 77.77% of his maximum heart rate. For this player, the median of the pulse rate is set to 142 ± 23 bpm, 71.71% of his HRmax, as it can be seen in Figure 1.

On the other hand, the analysis of variation in heart rate as a function of set time reveals a variation which again, is different for each of the players, as depicted in Table 4. Player 1 (blocker) has a HRmax median value of 152.33±17.52 bpm (82.60% HRmax) for Set 1 and a slightly higher value of 153.23±14.64 bpm (83.15% HR max) for Set 2. Furthermore, comparison of heart rate records between groups did not show significant differences (p=0.648), indicating that there was not a significant variation of the heart rate for each period.

Regarding Player 2 defender, a HRmax median value of 154.28±14.99 bpm (77.91% HR max) for Set 1 and a slight decrease in Set 2 to 139.73±14.51 bpm (72.39% HRmax). Again, comparing heart rate records between groups showed significant differences (p=0.001). Therefore, these data show that participation and work load delivered by Player 1 have been more intense as a result of a greater emphasis on the attack of the opposing team.

To explain the physiological response, it is important to describe the numbers of actions for each period (Table 5).

Table 4

<table>
<thead>
<tr>
<th>HR Values</th>
<th>Min (bpm)</th>
<th>Max (bpm)</th>
<th>Q1 (bpm)</th>
<th>Q3 (bpm)</th>
<th>IQR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Player 1</td>
<td>Set 1: 90</td>
<td>110</td>
<td>142</td>
<td>155</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Set 2: 110</td>
<td>174</td>
<td>150</td>
<td>157</td>
<td>16</td>
</tr>
<tr>
<td>Player 2</td>
<td>Set 1: 110</td>
<td>176</td>
<td>148</td>
<td>156</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Set 2: 106</td>
<td>146</td>
<td>131</td>
<td>139</td>
<td>15</td>
</tr>
</tbody>
</table>

Notes: Min = Minimum, Max = Maximum, Q1 = 25th percentile, Q3 = 75th percentile, IQR = interquartile range. *= p value significant comparing set 1 with set 2.

The total actions carried out by Player 1 (blocker) was 268, divided in 153 play actions in set 1 and 115 in set 2. Specially, on the one hand, the numbers of actions for each period (Table 5).

Table 5

<table>
<thead>
<tr>
<th>Frequency of actions</th>
<th>Serve</th>
<th>Reception</th>
<th>Setting</th>
<th>Attack</th>
<th>Block</th>
<th>Defense</th>
</tr>
</thead>
<tbody>
<tr>
<td>Player 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1</td>
<td>20</td>
<td>23</td>
<td>18</td>
<td>25</td>
<td>28</td>
<td>26</td>
</tr>
<tr>
<td>Set 2</td>
<td>18</td>
<td>20</td>
<td>13</td>
<td>24</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>Player 2</td>
<td></td>
<td></td>
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<td></td>
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<td>24</td>
<td>11</td>
<td>28</td>
<td>20</td>
<td>23</td>
<td>35</td>
</tr>
<tr>
<td>Set 2</td>
<td>24</td>
<td>15</td>
<td>12</td>
<td>24</td>
<td>15</td>
<td>26</td>
</tr>
</tbody>
</table>

Note: All values shown are in action times.

Discussion

The establishment of the working areas during actual game helps to determine the actual performance of players in real game situations (González Fimbres et al., 2016), in contrast to laboratory tests, that differ from the actual game situations in which the sport is played. Different aspects like field dimensions, quality of sand, weather conditions and number of players (Tili & Giatis, 2011) determine the physical demands of players. Therefore, these determining factors should be considered in beach volleyball as well, as they cause a physiological response that influences heart rate.

There are a few studies that deal with the physiological variables carried in male beach volleyball players. The study of the heart rate monitoring during three-set games in Portuguese players can be pointed out (Magalhaes et al., 2011). Despite not distinguishing between playing positions, results showed an average heart rate of 75% of HRmax, similar to those obtained in the present study with a workload between 77.71%-89.13% (HRmax) for Player 1 (blocker) and 66.10%–77.77% (HRmax) for Player 2 (defender). In the study of Magalhaes, no significant differences between analyzed sets were obtained, both for heart rate values and blood lactate values taken during games. However, this study recorded heart rate values with statistically significant differences for each set time only in Player 2 (defender).

This physiological response is related to different aspects of the beach volleyball game. In fact, the number of actions taken by a player or another is conditioned to the strategy of game used by the opposing team (Jimenez Olmedo, Penichet Tomas, Saiz Colomina, Martinez Carbonell, &jove Tossi, 2012). Players must undertake a greater number of game actions because each player must support the offensive load. Specifically, in the sample studied, Player 1 was the player who served and received the longest games (n=43) when compared to his partner (n=26). This meant that a greater load was applied to this player who had to perform more actions to develop the attack.

In addition, although there are different tactical elements in beach volleyball (Koch & Tlip, 2009b), not all of them have the same physical demands for the player. It is important to know that actions like blockades and attacks lead to an accumulation of fatigue which causes a jump lost up to 25% (Edwards, Steele, & McGhee, 2010). For this reason, the loss of 14% jump in sand with respect to land (Giatis et al., 2004), would help to explain the higher heart rate values in players who perform more attacks and blockades than those doing defenses and settings. Besides, a study on actions taken in beach volleyball players (Palao, Lopez-Martinez, Valades, & Ortega, 2015) states that blocker players take on average more jumps than defending players and even than players who exchange blocker and defender roles.

However, not only the number of shares or the player who performs determines the physiological response, but also the playing surface hinders the displacement (Smith, 2006) and the execution of movement patterns which are primarily offensive hued frontal displacements (Perez-Turpin, Cortell-Torno, Suarez-Llorca, et al., 2009) giving priority to the construction of the attacks and block actions.

On the other hand, another element to consider is the high temperatures that can be reached in a real beach volleyball game (Bahr & Reeser, 2012), which determine the cardiac response. In these environmental conditions, the cardiac response also plays a role since the loss of 1% of body weight due to dehydration drives an increase of 5-8 beats per minute (Coyle, 2004). This factor must be taken into account since the loss of fluids during a beach volleyball game is between 1039-1996 ml/h, which involves a dehydration level of between 0.8% and 1.14% (Zetou, Giatis, Mountaki & Kornmakiadou, 2008).

Furthermore, in order to understand the physiological response of players, the influence of the number of actions, both defensive and offensive, must be considered. This would explain the higher median value of HRmax recorded by Player 1 (blocker) against Player 2 (defender). Player 1 (blocker) performed more block and attack actions and more global actions than his teammate.

Finally, working time slots play a role in the cardiac response, as players have large time periods between points to undertake appropriate recovery. In this regard, previous studies established the temporal patterns of beach volleyball, but a more recent study establishes a ratio of 1:4.57 work time (Perez-Turpin, Cortell-Torno, Chinchilla-Mira, Cajueta-Anta & Suarez-Llorca, 2009) stating that players would have ample periods to ensure a proper recovery between points.

Conclusions

In this paper, optimal working areas and recovery of players for set time periods have been established through the combination of analysis.
methodology and registration of associated heart rate.

The specific work of each player, as a result of their playing position, has established differences in their physiological responses. For example, the blocker (Player 1) has shown a median HRmax value of 84.78% compared to 71.71% of the defending player (Player 2). Not only median values differed, but also their optimum working areas showed a difference. For the blocker, that area is established between 77.71% to 89.13% of HR max, while the defender is working on a less demanding area of between 66.66 to 77.77%.

Both players share the number of played actions, but Player 1 blocker carried out more defensive actions and blocks than Player 2 (defender) who performed more defensive actions and settings.

References


Callejon, D. (2006). Research and analysis of the serve in the area of between 66.66 to 77.77%.


